Evaluation of soil nutrient status in poplar forest soil by soil nutrient systematic approach

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Abstract: A study was conducted to evaluate the soil nutrient status of poplar plantation by Soil Nutrient Systematic Approach (SNSA) in Jianghan Plain, Hubei Province, China. Soil physiochemical properties were analyzed in laboratory through collection soil samples of study site. Ten treatments of application different fertilizers were designed such as CK, optimum treatment (N, P, K, Zn), -N(P, K, Zn), -P(N, K, Zn), -K(N, P, Zn), +Mg(N, P, K, Zn, Mg), -Zn (N,P,K), +2P(N, 2P, K, Zn), +2K(N, P, 2K, Zn), and 2N+2P+2K(2N, 2P, 2K, Zn) for field experiment to test the effect on tree height, diameter (DBH) growth, and dry weight of poplar. The results showed that there was no significant difference in tree heights between treatments with different fertilizers, diameter growth of poplar trees in treatments of lack of N and Zn was significantly slower than that of trees in optimum treatment, and dry weight of poplar dropped significantly for treatment of CK as well as treatments without application N and Zn. It is concluded that N and Zn were main limiting factor for poplar growth. Results from laboratory analysis and field experiment were uniform perfectly, which proved that SNSA was reliable in evaluating soil nutrient status of poplar plantation.

Keywords: Soil nutrient status; Soil Nutrient Systematic Approach; Poplar plantation; Limiting factor; Evaluation method; Soil physiochemical properties
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Introduction

Poplar is one of the most important rapid growth plantation tree species, which have broad adaptation and strong ability against bad conditions. The poplar plantation developed very quickly in recent years in China. On statistics, the area of poplar plantation in China was for 6.67×10^6 hm^2, which occupied 94.3% of total poplar plantation area in the world (FAO. 2003) and 14.8% of artificial forest area in China (Zhu 2000). To improve the condition of growth, especially improve nutrition condition, and accelerate the poplar's development are important issues that we have to face now. It is very clear that soil nutrient is the main source of poplar's nutrient. Therefore, how to evaluate the status of soil nutrient in poplar plantation simply and correctly is important. There are a few theories and methods for evaluating the plantation's SNS, but no one were widely accepted in China (He *et al.* 1998; Li *et al.* 1995; Wang 1996).

Soil Nutrient Systematic Approach (SNSA) was created by Hunter of Agriculture Serves International (ASI), which was used to appraise the SNS by laboratory analysis and field experiments (Hunter 1980). Portch (PPIC 1992) of Potash and Phosphorus Institute of Canada (PPIC) modified and introduced it into China for applying in agriculture. Nowadays, many researchers obtained great benefits for the research on crops and some fruit trees in China by using SNSA (Hong *et al.* 2000; Han *et al.* 1995; Chen *et al.* 1994; Tang *et al.* 2001). The potted experiments indicated the values of P and K by SNSA in 62 soil samples have strong relativity with that of crops that were planted in the experimented soil (Yang *et al.* 2000). Based on the status of soil nutrient in Chinese poplar plantation, we introduced SNSA into SNS evaluation. The purpose of this study is to evaluate poplar plantation's SNS by applying SNSA and to find out the limited factors of SNS in the experimental site.

Materials and methods

Experimental site

The study area is located in Gongan County, Hubei Province, China, belonging to subtropical monsoon climate. The total solar radiation is 4.6×10^5 $J\cdot cm^{-2}\cdot a^{-1}$, annual mean temperature is 16.4 °C, and annual precipitation is 1100–1300 mm. Annual mean frost-free period is 271d. Rice-rapeseed-rice is the main crop of rotation system in the site.

Soil sampling and preparation

Soil samples were taken from the site before field experiment. The randomly taken sub-samples were combined to form a sample in study site. And then, samples were air-dried, crushed, and passed through a 10 mesh stainless steel screen. The samples were analyzed in China-Canada Cooperate Soil and Plant Analysis Laboratory in Beijing by using SNSA (PPIC 1992).

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Field experimental design

According to laboratory analysis result, optimum treatment (OPT) was given by expert system (Hunter 1980; PPIC 1992). A field trail with 10 treatments was set up (Table 1). A completed random block design was adopted in 2001, with 4 replications, 4 m^2 (2 m×2 m) for each plot. The seedling (variety: *Zhonggong* 1) were planted in March 2001, and 16 trees for each plot. Fertilizer was applied during Mar. 2001 to Jun. 2002. Half of total fertilizers were used in March and June each year by furrow application. Poplar trees were cut down in Nov. 2002, height (H) and diameter at breast height (DBH) were measured. Data were analyzed with statistical software SPSS to estimate the rationality of using SNSA in research poplar forest's SNS (Waugh *et al.* 1966).

Table 1. Treatments and fertilizer quantity for field experiment ($kg \cdot hm^{-2}$)

No.	Treatments	N	P_2O_5	K_2O	$MgSO_4$	$ZnSO_4$
1	CK	–	–	–	–	–
2	OPT(N, P, K, Zn)	200	150	200	–	20
3	–N(P, K, Zn)	–	150	200	–	20
4	–P(N, K, Zn);	200	–	200	–	20
5	–K(N, P, Zn)	200	150	–	–	20
6	+Mg(N, P, K, Zn, Mg)	200	150	200	600	20
7	–Zn (N, P, K)	200	150	200	–	–
8	+2P(N, 2P, K, Zn)	200	300	200	–	20
9	+2K(N, P, 2K, Zn)	200	150	400	–	20
10	2N+2P+2K(2N, 2P, 2K, Zn)	400	300	400	–	20

Results and discussion

Soil samples analysis

The tested soils were podsol and showed little alkalescence. The content of organic material and total nitrogen was low (Table 2). According to standard of soil nutrient recommended by SNSA, the content of available P and exchangeable Mg was 3 times higher than critical value, which indicated that P and Mg in soil was not deficient. Available K was higher than critical value, which indicated that K was not lacking. However, the content of available N and available Zn were only 15% and 75% of critical value, respectively, which implied that N and Zn were deficient, and N was more deficient than Zn.

Table 2. Analysis result of soils in experimental field

	Organic matter (%)	pH	Total content (%)			Available content /$mg \cdot L^{-1}$				
			N	P	K	N	P	K	Mg	Zn
Content	1.70	7.63	0.126	0.075	2.24	11.43 (8.68–12.18)	49.0 (43–68)	103.3 (83.5–131.8)	420 (330–451)	1.50 (1.21–1.87)
Critical values	–	–	–	–	–	75	14	78	97.2	2.0

Notes: Numbers in bracket were change range of content for 7 soil samples.

Evaluation of field test

Effects of different fertilizers on tree height

From Fig.1A, the average heights of fertilized poplar trees were higher than that of no fertilizer application (CK), which showed fertilization accelerated the development of tree height. Except treatment 10, there was no significant difference in tree heights between treatments with different fertilizers.

Effects of different fertilizers on diameter (DBH)

Fig. 1B showed the effects of different fertilizers on diameter (DBH) growth of poplar trees. Compared with treatment 2, the diameters of popular trees with treatments 1, 3 and 7 were smaller than those with other treatments, which indicated that the diameter growth was slower when lacking N or Zn fertilizer. Double applications of N, P and K had no obvious effect on diameter growth compared with treatment 2 (OPT).

Effects of different fertilizers on dry weight

Dry weight of trees was the main evaluation criterion in SNSA (Hunter 1980). Our experiment showed that the dry weight of poplar trees in control group was only 55.9% of that in OPT treatment, and the dry weight of trees in lack of N treatment group was only 76.3% of that of trees in OPT treatment group, which demonstrated that N was deficient in soil (Table 3). In addition, the dry weight of tree in lack of Zn treatment group was 16.3% less than that of tree in OPT treatment group, which showed Zn was deficient also.

Excessive application of P (+2P) enhanced the imbalance between different elements in the soil, and the yield reduced significantly, compared with that of OPT treatment. The dry weights of trees in the –P, –K, +Mg and +2K treatments had no significant change, which indicated that those elements were not deficient in study site.

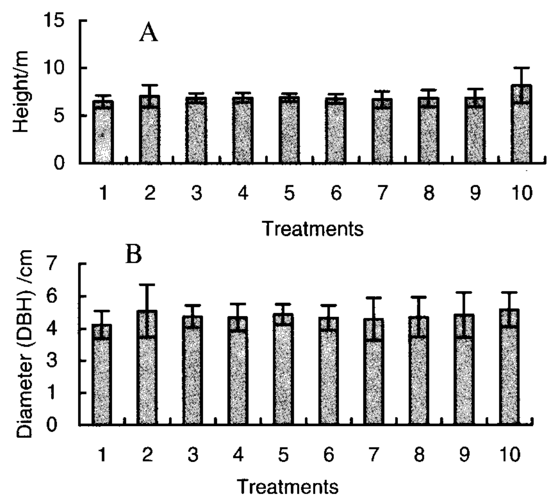

Fig. 2 Effects of different fertilizers on height growth (A) and diameter growth(B) of poplar trees

1---CK; 2---OPT(N, P, K, Zn); 3----N(P, K, Zn); 4-----P(N, K, Zn);5----K(N, P, Zn); 6---+Mg(N, P, K, Zn, Mg); 7----Zn (N, P, K); 8---+2P(N, 2P, K, Zn); 9---+2K(N, P, 2K, Zn); 10---2N+2P+2K(2N, 2P, 2K, Zn)

Conclusions

The results of field experiment indicated that except CK, other treatments had no marked effect on height of poplar, compared with that of optimum treatment. Diameter growth of poplar trees in treatments of lack of N and Zn was significantly slower than that of trees in optimum treatment. Dry weight of poplar dropped significantly for treatment of CK as well as treatments without application N and Zn, which indicated that N and Zn in the soil in experimental site were deficient. The results also showed that different application of P, K and Mg had no significant effects on poplar's dry weight, compared with optimum treatment, which demonstrated that those elements were not deficient in the soil. According to the field experiment, it is concluded that N and Zn were main limiting factor for poplar growth, and the deficiency of N was more severe than that of Zn. According to laboratory results, N and Zn were deficient in the soil, P and Mg were abundant, and K was adequate. Results from laboratory analysis and field experiment were uniform perfectly, which proves that SNSA was reliable in evaluating soil nutrient status of poplar plantation.

Table 3. Effects of different treatments on dry weight

Treatments	Average yield /kg	Standard deviation	Relative yield (%)	Soil nutrient status evaluation
CK	1.85^{**}	0.315	55.89	Lower yield if no fertilizer application
OPT	3.31	0.327	100	–
–N	2.52^{**}	0.378	76.32	Yield decreased significantly without N
–P	3.24^{ns}	0.282	97.89	P was not deficient in the soil
–K	3.30^{ns}	0.409	99.70	K was not deficient in the soil
+Mg	3.27^{ns}	0.355	98.79	Mg was not deficient in the soil
–Zn	2.77^{*}	0.428	83.68	Yield decreased significantly without Zn
+2P	2.74^{*}	0.297	82.78	More P was not needed in the soil
+2K	3.23^{ns}	0.385	97.58	More K was not needed in the soil
2N+2P+2K	3.43^{ns}	0.366	103.62	Double N, P, K was not needed in the soil

Notes: ^{ns}---not significant at 5% level; *---significant at 5% level; **---significant at 1% level.

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